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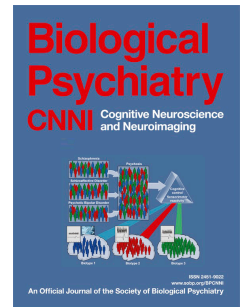
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Controversies in Computerized Cognitive Training

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Controversies in Computerized Cognitive Training.

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Abstract

Computerized cognitive training (CCT) to improve cognitive functioning is of enormous interest and has been applied in a broad range of populations with goals of improving both cognition and community functioning. Recent reviews presenting negative conclusions about CCT efficacy have inconsistent definitions of the treatment targets and cognitive improvement. They do not present an accurate representation of the typical process of CCT and cognitive remediation (CR), especially as delivered in major mental illnesses, such as schizophrenia. This review provides guidance on the definition of CCT and CR, the use of CCT and CR, and the definition and measurement of cognitive and functional gains. The review focuses on schizophrenia and healthy aging, with each population receiving unique CCT or CR approaches, and substantial extant literature with which to elucidate fundamental CCT and CR concepts and research findings. It is our conclusion that CCT has been shown in most studies to improve cognitive performance on untrained tests, in healthy older people and in people with schizophrenia. Functional gains in schizophrenia appear limited to CR studies. Clearly defining CCT, CR, and levels of treatment related gains will be critical for understanding the benefits of these widely used treatment programs.

Keywords; Schizophrenia; Healthy Aging; Computerized cognitive training; Cognition; Rehabilitation; Clinical trials

Introduction

Computerized cognitive training (CCT) is a rapidly growing topic. CCT uses software to train cognitive functions to improve them. The number of research papers has been increasing, as have the populations where CCT has been tested. There are published trials in schizophrenia, bipolar disorder, major depression, mild cognitive impairment (MCI), traumatic brain injury (TBI), cerebrovascular accident (CVA), Parkinson's disease, and multiple sclerosis. Additionally, there are a large number of trials evaluating CCT in healthy older populations. The level of interest in CCT is growing more rapidly than other areas of rehabilitation aimed at healthy aging, possibly due to the increasing evidence of efficacy, sophistication of delivery systems, and accessibility of these systems across different platforms. A Medline search for (computerized OR computer) AND cognitive AND (training OR remediation) yielded 2265 articles in the past 5 years and approximately 4200 articles published since 2000.

The Controversy About CCT

This increase in research is not without controversy. An open position statement was published in 2014 by over 70 scientists (1) arguing against the efficacy of CCT. The statement focused on commercial claims by companies that using their products would improve everyday outcomes, reverse cognitive decline, and prevent dementia. The statement also characterized the benefits of CCT as "small" and associated only with trained tasks. Despite substantial numbers of papers on the topic, the statement asserted that there was limited empirical evidence of efficacy. This position statement had substantial impact in the popular press, and preceded punitive action against a CCT software provider, Lumos Labs, and several others (e.g., Jungle Rangers, Learning Rx, and Carrot Neurotechnology), by the US Federal Trade commission on the basis of false advertising.

In 2016, a group of 111 scientists issued their own statement (2) taking issue with the prior statement and provided an annotated bibliography. This response reviewed the results from randomized clinical trials across multiple conditions examining changes in cognition and functioning. These scientists concluded that there was evidence of benefits associated with CCT. Importantly, the 2016 statement agreed that there are unsubstantiated claims of cognitive benefit. The two statements also agreed on the following: more research on CCT is needed, CCT does not cure or prevent Alzheimer's disease, CCT does not work as a vaccine with "one shot" being an adequate dose, and that physical exercise should not be overlooked as important for health.

The controversy continued with an extensive (83 page) review by Simons et al. (3), focused on methodological issues in the CCT research cited by the second position statement. The review focused on industry sponsored research and also concluded that there is a lack of evidence of CCT-related benefits. As described below, because of its selection criteria, the review omits published meta-analyses demonstrating efficacy for CCT and more recent studies with state-of-the-art interventions.

It is our contention that the 2014 position statement and the 2016 review paper come to the wrong conclusion, due to definitions of CCT and efficacy and limitations in the literature review. As there is no disagreement regarding excessive claims and no evidence for the reversal of dementia, this review paper evaluates evidence of CCT-related cognitive effects and associated benefits in schizophrenia and in the healthy aged. Both have substantial databases unmatched in other conditions. Further, there are substantial differences in these two populations in the prevalence and severity of impairment in cognitive and everyday functioning that help compare different CCT approaches.

Relationship Between Computerized Cognitive Training and Cognitive Remediation

The core of CCT is software designed to engage and practice cognitive functions. Some programs are explicitly aimed at a single cognitive domain, while others target an array of domains. Some CCT interventions also include interactions with trained facilitators. One role of a facilitator is to provide coaching to help improve training performance. Other “add-ons” to CCT include training of metacognitive strategies and “strategic monitoring.” The value added of these “add on” CCT activities is not fully understood but are believed, at a minimum, to enhance engagement in the CCT program.

The goals of CCT in people with schizophrenia are to improve cognition and to act as an adjunct to other interventions designed to improve everyday functioning. The strategy of training with CCT to improve functioning is based on the well-known connections between cognitive deficits and everyday disability (5-7). Many people with schizophrenia have skills deficits that partially respond to psychosocial skills training (8). These skills deficits have also been found to be correlated with cognitive performance and performance-based measures of functional capacity (FC; 9). The combination of CCT and skills training interventions has been studied to determine whether adding CCT to skills training leads to gains in skill acquisition and goal attainment (10-12). We will refer to interventions that combine CCT with psychosocial programs as “Cognitive Remediation” (CR), in line with previous definitions of this construct.

The current working definition for CR was established in 2005 by the Cognitive Remediation Expert Working Group, a group of international CR investigators and updated in 2012:

“Cognitive remediation is an intervention targeting cognitive deficit (attention, memory, executive function, social cognition, or meta cognition) using scientific principles of learning with the ultimate goal of improving functional outcomes. Its effectiveness is enhanced when provided in a context (formal or informal) that provides support and opportunity for improving everyday functioning.”

This context can include supports ranging from discussion groups to formal skills training. It is our position that the definitions of CCT in the 2014 statement and the 2016 review exclude CCT as it is usually delivered for people with schizophrenia. For instance, on page 149 it is said:

“Bowie, McGurk, Mausbach, Patterson, and Harvey (2014) compared cognitive training to functional training (or both). Like the Bowie et al. (2013) study of patients with depression, the cognitive training in Bowie et al.’s (2014) study of people with schizophrenia included other forms of training and therapy, so the observed benefits of cognitive training on cognitive outcomes cannot clearly be attributed to the brain-training software.”

As a result, studies that provided CR were excluded from consideration. These studies are important because CR randomized trials demonstrate the optimal environment for transfer of cognitive benefits to community functioning.

Measuring Efficacy of CCT

The main challenges in evaluating the efficacy of CCT (including in the context of CR) is the definition of different dimensions of improvement. Inconsistent terminology has been used in the past. Table 1 presents our conceptualization of the different levels of effects of CCT and CR.

Improvement on Training Tasks: Task Engagement

Essentially all current CCT programs measure training task performance. Performance on the training task is a process measure as opposed reflecting treatment-related gains. Although improvements in the training tasks may reflect engagement in training, they are not relevant to outcomes, and have been excluded from meta analytic studies, and will not be discussed further.

Improvement on Untrained Cognitive Tests: Near Transfer

The gold standard approach to measuring cognitive efficacy of CCT is the use of a battery neuropsychological tests. A prime example of such a battery is the MATRICS Consensus Cognitive Battery (MCCB; 17) containing 10 tests measuring broad cognitive domains. This battery was introduced in 2005 and its use has increased in frequency such that over 50% of published CCT trials in the past 10 years have used the MCCB.

As an example of how we define CCT-related cognitive benefits, the Useful Field of View (UFOV) is a cognitive test developed to assess attention and processing speed performance with relevance to driving (18). Subsequently, speed training aimed at the skills measured by UFOV have been tested in clinical trials (19-20) aimed at UFOV and driving performance. If after speed training, changes in either the UFOV or untrained tests (e.g., Digit symbol, serial learning, or Animal Naming) were detected then this would reflect near transfer. As we discuss in detail below, there are no broadly accepted standards for which cognitive tests are members of the same construct, thus we define improvements on any cognitive test that is untrained as transfer. Further, construct boundaries during training are not fully developed. It has been argued that adequate processing speed is required to perform the tasks assessing other constructs, such as verbal list learning paradigms. Increasing processing speed might improve task performance even though it might not affect “pure” memory ability. Multiple factor analysis results of cognitive performance in schizophrenia, particularly those with large samples ($n=4378:21$), routinely find a unifactorial structure, suggesting that arguments regarding construct boundaries are not supported at a measurement level.

Improvement on Functional Skills: Far Transfer

Evaluating far transfer of CCT and CR programs is generally based on at two types of measures. The first type is the ability to perform tests of FC. Tests of FC simulate real-world activities. Such tests are correlated with cognitive performance in people with schizophrenia and other conditions, as well as healthy aging (22). They are also consistently found to be correlated with independent living milestones, employment, and clinician ratings of everyday functioning (23). CCT does not teach these skills and improvements cannot reflect improvements on the trained task.

Improvement in Real World Functioning: Environmental Transfer

The second class of transfer measures is everyday functioning in the real-world environment. Environmental transfer is typically examined in trials where, for example, participants all receive a training intervention, such as vocational rehabilitation for people seeking employment, and a subset are randomized to also receive CCT.

Defining the Expected Benefits of CCT and CR

In the critical reviews the authors define CCT very narrowly but define the expected benefits very broadly. For example, studies (24-27) which used Thinking Skills for Work (TSW), a cognitive and vocational enhancement program, were not discussed in either the 2014 position statement or the 2016 review. This program uses commercially available software. Other CR programs that employ CCT, such as CIRCuiTs (28), were also excluded.

Based on the research included in the review, the authors appear to define CCT as a human-computer interaction without guidance or support. CCT alone as an intervention is not the typical strategy aimed at improving functional outcomes in clinical populations. Further, interventions employing CCT alone cannot be compared to comprehensive CR for their efficacy if CR studies are not considered.

Efficacy of CR in Near, Far, and Environmental Transfer in Schizophrenia

McGurk et al. (26-27) reported randomized controlled trials comparing evidence-based vocational rehabilitation including previous non-responders: Individualized Placement and Support (IPS) Supported Employment to IPS plus CCT using TSW. TSW includes approximately 24 hours of computer training using commercially available Cogpack software as well as coaching by a cognitive specialist on the application of cognitive training. Cognitive performance improved in the CR group compared to the IPS alone group, with significant improvements in processing speed/executive functioning, episodic memory, and the cognitive composite score. Job acquisition, time spent working and income earned, were higher in the CR group. Thus CR, which included CCT that improved cognitive performance, was superior to IPS alone, in that IPS is not a treatment as usual control, in that IPS is proven to be superior to standard of care for employment.

Bowie et al. (16) randomized outpatients with schizophrenia to CCT alone, a functional skills training program alone (FAST), or to CR therapy with CCT and FAST. Cognitive performance improved in the two groups where participants received CCT. FC (UCSD-performance based skills assessment; UPSA) improved in the two groups getting FAST training. These training effects were highly specific: cognitive improvements were not found for FAST training alone. UPSA scores did not improve in patients receiving CCT training alone. Real world functional outcomes, rated by blinded high-contact clinicians, improved significantly only in the CR group. Thus, this study allows for the separation of CR outcomes into near, far, and environmental transfer, with the combined treatment approach a CR “gold standard.” The limitation of this study was that there was not a “no treatment control.” This concern is obviated by the fact that the monotherapy treatments had different and statistically significant separable effects that in no way resembled a global placebo effect.

Domain-specific (social cognition, social competence) skills training has also been recently found to be augmented by CCT in people with schizophrenia (29-31). There are several studies to date that allow for separation of the efficacy of CR on these different levels of outcomes (near transfer, far transfer and everyday functioning).

There have been several studies in schizophrenia where CCT was administered without psychosocial interventions. Several studies used the same CCT training system, Posit Science Brain Fitness auditory training. The results of a large-scale study examined the benefits of training with Posit Science, unaccompanied by psychosocial interventions or support, compared to an active control group that played a limited video game (32). Analyses demonstrated significant near transfer for a composite neuropsychological measure, and in verbal learning, verbal memory, and speed of processing. Although the 2016 paper criticized these investigators for piecemeal publication, the final report stands on its own as a demonstration of near transfer to neuropsychological test performance, without far transfer and environmental transfer.

A further multicenter feasibility study (33) had the same design and found no effects on the MCCB composite score at end point (although there was a significant effect at the half-way point), as well as no far transfer to the UPSA. A large-scale registration trial, e-CAESAR (34), also found no separation of treatment and control conditions. A limitation of this trial was the long duration (130 training sessions) and the associated high rate of failure to complete the training (41% in active training).

Meta-Analyses of CCT and CR in Schizophrenia

There have been several meta-analyses of the efficacy of CCT and CR in schizophrenia. The first was published in 2007 (35), including 1,151 subjects in 26 randomized controlled trials with MATRICS-defined cognitive indices. Results indicated a moderate effect size (Cohen's $d=0.41$) on cognitive performance, without sufficient heterogeneity to explore potential moderators of cognitive effects. Age, education, ethnicity, symptoms, in- or outpatient status, or program characteristics, including length or intensity, type of training (computer based or other types), strategy (with or without strategy coaching), type of control (active vs. passive) or adjunctive psychosocial interventions did not

impact near transfer to neuropsychological test performance. More importantly, in the subset of studies that measured community functioning the delivery of a full CR intervention produced significantly greater functional effects than “stand alone” CCT. Thus, concomitant rehabilitation is a potent moderator the effects of CCT on community functioning.

A subsequent, larger meta-analysis (36) examined 2,104 patients who participated in 40 studies. The meta-analysis included studies that used computerized and non-computerized interventions, with no statistically significant moderator effect of delivery. Further, 25% of the studies had a follow-up assessment of cognition and functioning, after end of treatment. Among the main findings of this review were that there was a statistically significant moderate effect size for near transfer to global cognition (.45) with significant far transfer to everyday functioning at the end of the studies (.42). At follow-up, cognitive gains were found to be persistent (.43) as were functional gains (.37). Functional gains were generally limited to studies with psychosocial interventions. Importantly, methodological quality of the studies and estimates of the effect size on cognition and everyday functioning did not differ between studies with a higher and lower risk of bias. This makes this type of intervention very different from the widely accepted cognitive behavior therapy intervention for schizophrenia where effect sizes diminish with better quality studies (37).

CR interventions led to greater functional gains than CCT alone. In these studies, the concurrent psychosocial interventions in the CR studies did not impact near transfer to untrained cognitive tests (a finding replicated since then by Bowie et al). Patients with more severe symptoms had fewer gains and although there were no age effects, the age range was limited. Several reviewed studies reported age effects and this has also been reported by studies after this review (38-40). Active vs. passive control group did not influence effect sizes.

Efficacy of CCT and CR in Schizophrenia.

Meta analyses and studies performed since these meta analyses have found consistent evidence that CCT produces near transfer to untrained neuropsychological tests. These meta analyses were not mentioned in the 2016 review, despite being widely cited (1023 citations for McGurk et al, and 1030 citations for Wykes et al.) and readily accessible. Functional gains occurred mainly with CR, but recent studies suggest CCT alone may affect costs of care (41-42). The CCT studies in schizophrenia have not found far transfer to functional skills in the absence of targeted training.

CCT in Healthy Older Adults

There are more than 200 published papers in the field of CCT for healthy older adults. To evaluate the current state of the evidence, we review the four largest (by enrolled participant number) randomized controlled trials performed in healthy older adults and several recent meta-analyses.

Four Large Randomized Controlled Trials

ACTIVE: The Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) study was the first study designed as a pivotal study to evaluate the efficacy of cognitive training in healthy older adults (43). ACTIVE enrolled 2,832 adults over the age of 65 across six recruitment sites in the United States with a focus on obtaining an ethnically and socioeconomically representative sample. Participants were randomized into a control group (no treatment) or one of three treatment groups, memory strategy training (instructor led, not computerized), reasoning training (instructor-led, not computerized), or speed training (adaptive computerized training). Each treatment group received 10 sessions of classroom-based training (one hour each, twice per week, for five weeks). Following the intervention, participants who had completed 8 or more sessions were randomized to either receive four booster sessions at 11 and 35 months after the initial training or not.

Each cognitive training program significantly improved performance on within-domain cognitive tests relative to the control group, documenting near transfer (44). Effect sizes were large immediately following training, and declined over time, but were still significant at the ten-year follow-up. As hypothesized, training effects did not generalize to neuropsychological tests in other training domains. The booster subgroup of speed training showed improved performance on the functional speed measure at the two-year (44) and five-year follow-up (45), documenting transfer. Each condition showed slower IADL decline relative to the control group, with no effect seen at the two years (44); all trained groups showed similar effect sizes at the five-year follow-up (45); speed and reasoning training groups showed significant effects at the ten-year follow up (46). Effects on IADL decline are interpreted as environmental transfer of the cognitive training.

Secondary outcome analyses demonstrated that speed training had a significant environmental transfer effects on driving cessation (47), driving habits (48), and at-fault crash incidence based on department of motor vehicle records (49), as well as health-related quality of life (50-51), depression (52), locus of control (53), and medical expenditures (54). A publication (55) based on the 10-year outcomes showed that speed training was associated with a 29% reduction in hazard ratio of dementia, while the other two interventions were not.

IHAMS: The Iowa Healthy and Active Minds Study was designed to replicate the results from ACTIVE speed training with three main design differences: an active control, a broader age range of participants, and comparison of training locations (56). IHAMS enrolled 681 adults (stratified into 50-64, and 65+ age ranges), randomized into one of four groups including active control (computerized crossword puzzles), an in-clinic training group, and in-clinic training group with booster, and an at-home training group. Core training was for ten hours (as ACTIVE), with the booster groups of four sessions in month 11. A priori outcomes included measures of near transfer (a primary measure UFOV, and a set of standard neuropsychological measures of speed, attention, and executive function) and environmental transfer (IADLs and depressive symptoms). All

three training groups showed significant near transfer to primary and secondary neuropsychological measures relative to the crossword puzzle control group (57), and the booster group showed significant far transfer to the IADL and depression as well (58).

IMPACT: The Improvement in Cognition with Plasticity-based Adaptive Cognitive Training study was designed as a pivotal trial for an auditory speed training program (59). IMPACT enrolled 487 adults aged 65+, randomized into a treatment group and an active control group (DVD based educational courses with pencil & paper quizzes). Core training was for forty hours over eight weeks. A priori outcomes measures included two performance-based composite neuropsychological measures of memory and a participant-reported outcome measure reflecting real-world cognitive experience. The training group showed significant near transfer on both the composite memory assessments relative to the active control group, and far transfer to the everyday cognition measure. Follow-up after a three month no-training period showed some decline on the one of the composite memory assessments and on the everyday cognition measure (60).

BGTT: This study was designed as an evaluation of brain training in collaboration with the British television show *Bang Goes the Theory* (BGTT). A novel feature of the study was that it was executed entirely online with no direct participant contact. The study compared two cognitive training programs (one focused on reasoning, and the second covering a broad range of cognitive skills), to a control group that answered trivia questions (61). A first evaluation focused on 11,430 participants under 50 who completed a pre- and post-training assessment and at least two training sessions. No improvements were seen for either training group relative to the control on any of four composite cognitive measures. This first evaluation received substantial attention (more than 800 citations) due to its innovative trial design, negative result, and publication in *Nature*. A second evaluation was published five years later, focused on 2,921 participants aged over 50. Importantly, this second study was performed by the same study team as the first study. This evaluation showed a positive effect of both training groups on the primary outcome measure, IADLs, as well as on multiple secondary outcome measures of composite cognitive function (62). Interestingly, this study appears much less widely known (42 citations), despite the fact that older participants were trained and the finding that both environmental transfer and near transfer to untrained tests were found.

Meta Analyses of CCT in Healthy Older People

Given the interest in CCT for healthy older people, there have now been multiple meta-analyses published. We focus here on the two most recent.

Lampit et. al. (63) analyzed 52 studies with 4,885 healthy older adults. They found a significant overall effect for CCT versus control on cognitive function. Domain analysis documented significant effects in multiple cognitive domains with the exception of executive function and attention. Moderator analyses showed that home-based administration was not effective compared to group-based training, and that more than three training sessions per week was not as effective as three or fewer. Interestingly, there

was no difference in effect size for control participants between studies with active vs. passive controls, suggesting a limited placebo effect.

Mewborn et. al. (64) analyzed 97 studies including those with healthy older adults or participants with mild cognitive impairment. They found a significant overall effect of CCT versus control on cognitive function. No significant differences were found for age, education, and cognitive status. Again, there was no significant difference in effect size between studies with active and passive controls. The analysis specifically evaluated near-transfer within the trained and untrained domains, finding greater near transfer effects within the trained domains, but statistically significant effects for both.

We identified a total of eight systematic meta-analyses of CCT in older adults published over recent years (2014-2017), and each comes to similar conclusions (65-70). The exception appears to be working memory training, where considerable debate continues to occur, e.g.(71-72). We suggest this is consistent with the idea that CCT approaches are distinct and evaluating the efficacy of programs by general type of approach (69) and specific implementation (65,70) will be a fruitful approach going forward.

Summary of Efficacy of CCT in Normal Aging.

CCT interventions in healthy older adults have been very diverse, ranging from casual games to structured scientifically derived exercises. Four large randomized controlled trials and multiple meta-analyses have found consistent evidence that CCT improves cognitive performance and real-world function in healthy older adults. Given the use of ordinary games and cognitively stimulating activities as control activities, and the distinct efficacy profiles of distinct interventions in ACTIVE, the clinical data document that distinct CCT approaches have distinct effects. Environmental transfer has been shown in several studies without targeted skills training.

General Summary

The Strengths of the Existing Data on CCT in Normal Aging and Schizophrenia

In response to the 2016 review, we note that concerns regarding individual studies are best addressed by considering results from the largest studies, and by considering meta-analyses incorporating results from all relevant studies. As discussed above, the four largest trials conducted with older adults in CCT, collectively enrolled 6,921 participants and collectively showed cognitive and functional benefits. In schizophrenia, several large well-designed trials with CR have shown cognitive and functional benefits; while meta-analyses have confirmed the generality of these effects. These meta analyses were not cited in the 2016 review. Given results from the largest trials and from the meta-analyses in both normal aging and schizophrenia, the argument that existing trials are insufficient to establish the benefit of CCT is not consistent with the literature.

Improvement on Neuropsychological Measures of Cognition Does Matter

One of the major points of critiques stating that CCT does not improve cognitive performance is the assertion that the outcome measures employed are the same as the

training measures. The authors of the 2016 review decided that any cognitive improvements shown on tests of a construct that was trained in the intervention were unimportant (e.g., if verbal memory was practiced in the intervention, improvements on neuropsychological tests of verbal memory were deemed as not reflecting real transfer).

These arguments are applied to a study published by Fisher et al., (74) wherein participants with a diagnosis of schizophrenia treated with a CCT program manifested a large composite score improvement compared to a video game comparison group.

(p135):

“The tasks that did show differential improvements following cognitive training were distinct from the tasks that were used during training, but they tapped some of the same underlying constructs (e.g., learning and memory). Improvements were limited to these trained domains, suggesting relatively narrow and focused training benefits rather than broad improvements to cognition more generally.”

These arguments have flaws. The first is actually the simplest to address. Why would improvement in a single cognitive domain be unimportant? What if memory training made memory impairments in cortical dementia such as Alzheimer’s disease go away?

The second flaw requires a more sophisticated analysis. Using this logic, one could argue that if memory training is provided on list learning and tested on untrained paragraph learning, that any improvement on paragraph learning does not reflect true improvement because they are “closely related”. This approach leads to the dismissal of many positive findings from CCT studies. The concept of “closely related” lacks a scientific basis. Classical neuropsychology textbooks do not mention “closely related” as a defining feature of cognitive tests. Neuropsychological tests are typically organized into scientific constructs, such as processing speed, executive functioning, and working memory. Definitions of constructs have focused on inter-correlations between indicators of the construct and reduced correlation with indicators of other constructs meaning that indicators of the same construct should be related but not redundant. However, the indicators of these constructs are not interchangeable.

In a recent large-scale study of people with schizophrenia (n=2526) tested with the MCCB (75), individual processing speed tests manifested only moderate overlap with MCCB processing speed construct scores calculated without that test. Specifically, verbal fluency correlated $r = .47$ with the processing speed construct defined by Trail making part A and BACS symbol coding, while Trail making part A correlated with the construct defined by verbal fluency and BACS symbol coding at $r = .57$. The variance shared is at most 32%. The moderate levels of inter-correlation between exemplars of the same scientific construct suggests that “closely” needs a more precise definition. Further, this argument is applied to the ACTIVE study, asserting that improvements on independent processing speed tasks lack importance if participants are receiving speed focused training. Thus, the authors are in some way stating that UFOV, symbol coding, Trail Making, and animal naming are essentially identical tasks, which is not consistent with the correlational data presented above.

Improvement on Real-World Measures Has Been Shown

A further significant critique from the 2014 position statement and the 2016 review was that "far transfer" - variously described as transfer to untrained measures or measures with real-world significance - has not been shown. We separate far transfer to cognitively demanding functionally relevant tasks, such as FC assessments or driving simulators, from real-world gains. Studies in healthy aging have shown improvement on real-world measures ranging from IADLs to health-related QoL, to driving safety and patient-reported outcomes. Studies in schizophrenia have shown improvement on environmental transfer measures ranging from employment to social relationships to independent living; and the most recent meta-analysis concludes cognitive benefits of a medium effect size, with similar functional improvement in CR studies. Given the results from trials and meta-analyses in both normal aging and schizophrenia, the argument that transfer to real-world measures has not been shown in studies of CR is not consistent with the evidence.

Conclusion

The controversy regarding whether CCT has a benefit is based on definitional inconsistencies, including overly narrow definitions of CCT that exclude CR and overly narrow definitions of transfer. As discussed above, we believe that the scientific literature shows that CCT (fully defined, including CR) benefits participants across a variety of definitions of transfer. Given the evidence from individual randomized controlled trials and from relevant meta-analyses, it is appropriate now for research efforts to expand from evaluation of *efficacy in research settings* (although such studies should certainly continue) to include the evaluation of *effectiveness in real-world settings*, with a focus on implementation methods, real-world use in partnership with health care providers and real-world treatment settings, using cost-effectiveness and patient-centered outcome measures.

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Table 1

Levels of Efficacy of CCT/CR

Level	Terminology
1. Improved performance on Training tasks	Training Engagement ¹
2. Improved Cognitive Performance on non-trained tasks	Near Transfer ²
3. Improved Performance on Cognitively Demanding Functional Tasks	Far Transfer ³
4. Improved Everyday Functioning	Environmental Transfer ⁴
<p>1. This is measured by improved performance on training tasks over time, which can be reflected by speed, accuracy, or both.</p> <p>2. This includes all neuropsychological tests that were not part of the computerized training procedures.</p> <p>3. This can include direct simulations of everyday activities, like driving simulators, or performance-based measures of other everyday functional skills</p> <p>4. Can include work, social, self-care, and driving activities</p>	